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POWDER MOLDING METHOD

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POWDER MOLDING METHOD

[Funmatsu seikei hoho]

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[There are no amendments to this patent.]

Claim /2*

A powder molding method characterized by the fact that the following steps of operation are performed in order:

a step in which a molding die for powder molding equipped with die surfaces that define the molding cavity and a molding powder substantially free of lubricant are used,

and in which a heating operation is performed to heat said molding die and said molding powder to within a temperature range of 150-400°C, and, at the same time, a coating operation is performed to coat said lubricant on the die surfaces of said molding die;

a step in which said molding powder heated to a temperature in said range is filled in the molding cavity of said molding die heated to a temperature in said range;

* [Numbers in right margin indicate pagination of the foreign text.]

and a step in which said molding powder filled in said molding cavity is compression-molded to form a green compact.

Detailed explanation of the invention

[0001]

Technical field of the invention

This invention pertains to a powder molding method for making compression-molding of powder to form green compact.

[0002]

Prior art

In the conventional powder metallurgy, zinc stearate or other lubricant is added in the molding powder so as to guarantee the lubrication property of the molding powder. US Patent No. 4,955,798 described a warm powder molding method characterized by the following facts: a molding powder for powder metallurgy and containing a solid lubricant is used; the molding powder is heated to a temperature in the range from room temperature to a temperature without melting of the solid lubricant, that is, in the range of 70-150°C, or preferably 70-120°C; and the heated molding powder is compression-molded using a molding die to form a green compact.

[0003]

Also, Japanese Kokai Patent Application No. Hei 5[1993]-271709 described a technology in which a lubricant for high-temperature use is added, and the lubricant is a product of a reaction among the following components: 10-30 wt% of C10-22 monocarboxylic acid, 10-30 wt% of C10-22 dicarboxylic acid, and 40-80 wt% of diamine represented by $(CH_2)_x(CH_2)_2$ (x: 2-6). This type of lubricant can be used as a powder metallurgical lubricant at 370°C or lower.

[0004]

Problems to be solved by the invention

However, in order to increase the density of the powder particles themselves, one may increase the heating temperature of the powder. Yet when the molding powder is heated to 150°C or higher, fluidity of the lubricant added in the molding powder degrades significantly, and it is impossible to obtain a green compact with a high density. Even in the technology of said US Patent No. 4,955,798, although it is possible to guarantee fluidity of the molding powder if the temperature is lower than 150°C, when the temperature is over 150°C, the lubricant melts, and fluidity of the molding powder degrades significantly, so that it is impossible to fill the

powder in a powder box or the like, and this is unfavorable for continuous molding operation (unfavorable for productivity).

[0005]

For the technology described in Japanese Kokai Patent Application No. Hei 5[1993]-271709, as the melting point is higher than that of the conventional lubricant, it can be used at 370°C or lower, yet fluidity of the powder degrades at temperature of 150°C or higher. Due to the aforementioned facts, in the conventional warm powder molding method, the heating temperature of the powder is lower than 150°C.

[0006]

The objective of this invention is to solve the aforementioned problems of the prior art by providing a powder molding method preferred in improving the density and strength of the green compact.

[0007]

Means to solve the problems

In order to realize the aforementioned objective, the present inventors have performed extensive research. As a result of this research work, it was found that the molding powder can be compression-molded to form a green compact with improved density and strength when the following method is adopted: a molding powder substantially free of lubricant is used; both the molding powder and molding die are heated to a temperature in the range of 150-400°C, and a lubricant is coated on the die surfaces of the molding die; then the molding powder is compression-molded to form a green compact.

[0008]

That is, this invention pertains to a powder molding method characterized by the fact that the following steps of operation are performed in order: a step in which a molding die for powder molding equipped with die surfaces that define the molding cavity and a molding powder substantially free of lubricant are used, and in which a heating operation is performed to heat said molding die and said molding powder to a temperature in the range of 150-400°C, and, at the same time, a coating operation is performed to coat said lubricant on the die surfaces of said molding die; a step in which said molding powder heated to a temperature in said range is filled in the molding cavity of said molding die heated to a temperature in said range; and a step in which said molding powder filled in said molding cavity is compression-molded to form a green compact.

[0009]

Embodiment of the invention

A conventional die having die surfaces that define the molding cavity may be used as the molding die adopted in the method of this invention. A conventional metal powder substantially free of lubricant may be adopted as a molding powder adopted in the method of this invention. Consequently, the molding powder adopted in the method of this invention usually is not entirely free of lubricant. Conventional materials, such as iron based materials, Ni based materials, copper based materials, aluminum based materials, etc., may be used as the metal powder. As the metal powder, the conventional types, such as sprayed powder, electrolytic powder, reduced powder, etc., may be adopted.

[0010]

When the molding powder is heated to a high temperature, although improvement is realized with respect to the softening property and moldability of the molding powder, oxidation of the molding powder may also be accelerated. Also, if the heating temperature of the molding powder is low, although it is favorable in suppressing oxidation of the molding powder, softening property and moldability of the molding powder nevertheless degrade. Also, when the size of the powder particles of the molding powder is small, the specific surface area of the molding powder becomes larger, and the molding powder is prone to activation and oxidation.

[0011]

The heating temperature of the molding powder is determined in consideration of this fact. Depending on the particle size of the powder particles, the heating temperature of the molding powder has its upper limit set at 350°C, 300°C, 250°C, or 200°C, and has its lower limit /3 set at 170°C, 200°C, or 230°C. However, this invention is not limited to said temperatures.

[0012]

Also, if the heating temperature of the molding die becomes higher, although the moldability of the molding powder is improved, the lifetime of the molding die becomes shorter. This is undesired. On the other hand, if the heating temperature of the molding die becomes lower, although the lifetime of the molding die becomes longer, the moldability of the molding powder may degrade. The heating temperature of the molding die is determined in consideration of these facts. Depending on the type of the material of the molding die, the heating temperature of the molding die has its upper limit set at 350°C, 300°C, 250°C, or 200°C, and has its lower limit set at 170°C, 200°C, or 230°C.

[0013]

According to the method of this invention, when the molding powder is of iron type and the molding die is also of iron type, in consideration of the aforementioned facts, it is preferred that the molding powder and molding die be in the range of about 150-300°C. However, this invention is not limited to this range. Means for heating the molding powder and molding die include IR heating, heater, induction heating, joule heating, etc.

[0014]

According to the method of this invention, the molding die and molding powder are heated to a temperature in the range of 150-400°C. One may have the heating temperature of the molding die substantially equal to the heating temperature of the molding powder, or have them be different from each other. When the heating temperature of the molding powder is higher than the heating temperature of the molding die, the lifetime of the molding die can be guaranteed, while the moldability of the molding powder can be guaranteed. As a result, it is favorable in guaranteeing the density of the green compact.

[0015]

On the other hand, when the heating temperature of the molding die is higher than the heating temperature of the molding powder, transfer of heat from the molding powder to the molding die is suppressed. Consequently, this is favorable in maintaining the temperature of the molding powder. As a result, it is favorable in guaranteeing the density of the green compact. In particular, as heat of the outer layer portion of the green compact is guaranteed, it is favorable for maintaining the surface temperature of the green compact, and thus for forming a finer surface of the green compact.

[0016]

The atmosphere for heating the molding powder can be selected corresponding to the type of the molding powder. It may be performed in the ambient atmosphere or in a non-oxidative atmosphere. Examples of the non-oxidative atmosphere include reduced pressure atmosphere, vacuum atmosphere, nitrogen atmosphere, rare gas atmosphere, etc. Also, a reductive atmosphere may be adopted. The same is true for the atmosphere for heating the molding die. According to the method of this invention, a lubricant is coated on the die surfaces of the molding die. As a result, friction between the molding powder and the die surfaces of the molding die can be reduced, and filling of the molding powder becomes easier. Conventional types of lubricants can be adopted as the lubricant in this case. One may adopt a solid lubricant

or adopt a lubricant prepared by dispersing or dissolving a solid lubricant in a solvent. Examples of the lubricants that may be adopted include zinc stearate based lubricants, graphite based lubricants, boron nitride based lubricants, metal soap based lubricants, etc. Examples of solvents include water, alcohol, etc. As far as the coating means is concerned, one may adopt spray coating, brushing, dipping, and other conventional methods.

[0017]

According to the method of this invention, there is a step of heating operation in which the molding die and molding powder are heated to a temperature range of 150-400°C, and there is a step of coating operation in which a lubricant is coated on the die surfaces of the molding die. In this case, one may perform the coating operation after the heating operation, or perform the heating operation after the coating operation, or perform the heating operation and coating operation at the same time.

[0018]

Application examples

In the following, this invention will be explained in more detail with reference to application examples. First of all, explanation will be made on molding die (1) with reference to Figure 1. Molding die (1) has die mold (11) made of a metal in ring shape and functioning as a fixed die with a die hole, die holder (12) made of a metal in ring shape and holding the peripheral portion of die mold (11), upper punch die (13) made of a metal and capable of lifting with respect to die mold (11), and lower punch die (14) made of a metal and fit to the die hole of die mold (11). Said lower punch die (14) is held on base portion (15).

[0019]

Molding cavity (17) is defined with the die surface of the die hole of die mold (11), the die surface of lower punch die (14), and the die surface of upper punch die (13). Upper punch die (13) is equipped with first heater (13c) for heating it. Die mold (11) is equipped with second heater (11c) for heating it. In addition, movable powder box (2) that can move along guide (2x) is equipped above die holder (12) and die mold (11). Powder box (2) has containing chamber (2e) that contains the molding powder. Containing chamber (2e) has upper surface opening (2h) and lower surface opening (2k). On powder box (2), spray nozzle (3) for spraying the lubricant is equipped via arm (3m). Powder box (2) has third heater (2c) for heating molding powder P in containing chamber (2e).

[0020]

Also, powder feeder (7) is set near molding die (1). Powder feeder (7) is composed of powder container (70) that contains molding powder P, feeding channel (71) that is set extending from powder container (70) downward to above containing chamber (2e) of powder box (2) in standby state, valve (72) for opening/closing feeding channel (71), and fourth heater (73) for heating molding powder P in feeding channel (71). Said first heater (13c), second heater (11c), third heater (2c), and fourth heater (73) are controlled with a temperature controller not shown in the figure, and they are maintained at their respective target heating temperatures.

[0021]

When this molding die is used in this application example, die mold (11) is heated to a prescribed temperature range by means of second heater (11c), and upper punch die (13) is heated to a prescribed temperature range with first heater (13c). Also, molding powder P of powder container (70) is heated to a prescribed temperature range by means of fourth heater (73) of powder feeder (7). In this application example, the target heating temperature for molding die (1) is in the range of 150-400°C, and the target heating temperature for molding powder P is in the range of 150-400°C.

[0022]

As shown in Figure 1, powder box (2) is set in standby state at standby position M separated from molding cavity (17). When valve (72) of powder feeder (7) is turned ON, heated /4
molding powder P falls naturally from powder feeder (7), and it is fed to containing chamber (2e) of powder box (2). The molding powder in containing chamber (2e) of powder box (2) is heated with third heater (2c), and it is set in standby state within a prescribed temperature range in containing chamber (2e).

[0023]

At a prescribed time, as shown in Figure 2(A), powder box (2) is driven to move in the direction indicated by arrow X1 by means of cylinder (2p). Consequently, as shown in Figure 2(B), spray nozzle (3) becomes opposite to molding cavity (17) and upper punch die (13), and powder box (2) is stopped at the position. In this state, spray nozzle (3) is turned ON, lubricant L is sprayed from spray nozzle (3) in the upward and downward directions. As a result, lubricant L is coated on the die surface of die mold (11), the die surface of lower punch die (14), and the die surface of upper punch die (13). That is, "die lubricating" operation is carried out as lubricant L is coated on the die surfaces of molding die (1).

[0024]

In this application example, because die mold (11) and upper punch die (13) are heated to a high temperature, liquid lubricant L is quickly dried under their heat. Consequently, a lubricant film is laminated on the die surface of die mold (11), the die surface of lower punch die (14), and the die surface of upper punch die (13). Consequently, it is possible to omit or simplify the drying operation for drying liquid lubricant L, and this contributes to increase of the production efficiency.

[0025]

After end of coating as the "die lubricating operation", powder box (2) is further driven to move in the direction indicated by arrow X1. As shown in Figure 2(C), lower opening (2k) of containing chamber (2e) of powder box (2) becomes opposite to molding cavity (17). Then, molding powder P in containing chamber (2e) of powder box (2) falls naturally under its own weight to fill molding cavity (17). After end of filling, powder box (2) is driven to move in the direction indicated by arrow X2 and is returned to standby position M. Then, upper punch die (13) is lowered in the direction indicated by arrow Y1, and it is pressed into molding cavity (17) to form a green compact. Therefore molding powder P in molding cavity (17) is compression-molded and a green compact is molded.

[0026]

In this application example, friction between molding powder P in molding cavity (17) and the die surface of molding die (1) is reduced by said lubricant film. As a result, filling property and compression-molding property of molding powder P are improved. After molding of said green compact, the following steps of operation are performed: a sintering step in which the green compact is heated to the sintering temperature range to form a sintered body, and a forging step in which the sintered body is hot forged with a forging die to form a sintered forged body.

[0027]

In this application example, when molding powder P and molding die (1) are heated, the heating temperature of molding powder P and the heating temperature of molding die (1) may be substantially identical to each other. Also, one may have the heating temperature of molding powder P higher than the heating temperature of molding die (1). In addition, one may have the heating temperature of molding die (1) higher than the heating temperature of molding powder P. When the heating temperature of molding powder P is higher than the heating temperature of

molding die (1), it is favorable for guaranteeing the moldability of molding powder P, and it is thus favorable for guaranteeing the density of the green compact.

[0028]

When the heating temperature of molding die (1) is higher than the heating temperature of molding powder P, even when molding powder P is in contact with the die surface of molding die (1), it is possible to suppress escape of heat of molding powder P to molding die (1), so that it is favorable for maintaining the temperature of molding powder P. In this sense, it is favorable for guaranteeing the density of the green compact. Especially, it is possible to guarantee the temperature of the surface layer portion of the green compact in contact with the die surface of molding die (1). Consequently, this is favorable for maintaining the surface temperature of the green compact. This is favorable for avoiding or reducing the surface pores.

[0029]

In the aforementioned example, coating operation by spraying lubricant L and loading operation by having molding powder P in powder box (2) naturally fall into molding cavity (17) are carried out while powder box (2) is stopped. However, this invention is not limited to this scheme. It is also possible to perform the aforementioned coating operation and loading operation while powder box (2) is driven to move at a low velocity instead of stopping it. In the aforementioned application example, there is a forging step of operation in which the sintered body prepared by sintering the green compact is forged is. However, this invention is not limited to this scheme. One may also omit the forging step, depending on the specific application of the green compact.

[0030]

Also, one may perform the operation in the example shown in Figure 3. In this case, in addition to shutoff lid (2r) for opening/closing upper opening (2h) of containing chamber (2e) of powder box (2), and shutoff lid (2s) for opening/closing lower opening (2k), containing chamber (2e) is connected to evacuating device (9) through evacuating channel (9n) and shutoff valve (9v). As evacuating channel (9n), a rubber hose, a bellows tube, or other stretchable, bendable and flexible tube may be adopted. In this way, it allows movement of powder box (2). For example, a vacuum pump may be used as evacuating device (9).

[0031]

Then, as the molding powder in containing chamber (2e) is heated with third heater (2c), containing chamber (2e) is in reduced pressure state or vacuum state by means of evacuating

device (9) and it stands by in this state. At end of the standby time, powder box (2) is driven to move in the direction indicated by arrow X1. When powder box (2) reaches a prescribed position, shutoff lid (2r) and shutoff lid (2s) are opened, or, in some cases, only shutoff lid (2s) is opened, so that molding powder P in powder box (2) falls into molding cavity (17). As a result, because containing chamber (2e) is under a reduced pressure or in vacuum state in standby, oxidation of molding powder P at a high temperature can be suppressed. This is favorable.

[0032]

Because it is favorable for suppressing oxidation of molding powder P, it is possible to further increase the heating temperature of molding powder P. As a result, the density of the green compact is further increased, and it contributes to guarantee the quality of the green compact, sintered body and sintered forged body. In addition, as shown in Figure 3, one may also adopt the following scheme: shutoff (70s) for opening/closing powder container (70) of powder feeder (7) is set on said powder container, and, at the same time, powder container (70) is connected to evacuating device (9) through evacuating channel (9m) and shutoff valve (9w). In this case, it is possible to suppress oxidation of the molding powder at a high temperature in powder container (70).

[0033]

(Test examples)

In order to check the effects of the method of this invention, the following tests were performed.

(Test Example 1)

① In this test, a mixture of iron based powder and graphite powder was used as the molding powder, and the molding surface pressure for molding the green compact was set at the same value of 7 ton/cm^2 in both the application examples and comparative examples. In each /5
application example and comparative example, a green compact was formed, and the density of the green compact was measured. Measurement of density is based on the standard of Japanese Powder Metallurgical Industry Association (JPMA M 01-1992). Also, in both application examples and comparative examples, the proportion of the graphite powder in the molding powder is 5 wt%.

[0034]

The iron based powder adopted in both the application examples and comparative examples has a commercial name of Distaloy AE (Hoganas Co). Target composition of Distaloy

AE by weight is of Fe, 4% Ni, 1.5% Cu and 0.5% Mo. Particle size distribution of Distaloy is as follows: 8% of particles with size of 150 μm or larger, 20% of particles with size of 45 μm or smaller, and balance of particles with size of 45 to 150 μm.

[0035]

In Application Example 1, said molding powder without lubricant is used. Together with die lubrication, in a state in which the molding temperature is set at 150°C, that is, in a state in which target temperature of both the molding powder and the molding die is set at 150°C, a green compact is molded. In Application Example 2, said molding powder without lubricant is used. In the same way as aforementioned, together with die lubrication, in a state in which the molding temperature is set at 180°C, that is, in a state in which the temperature of both the molding powder and the molding die is set at 180°C, a green compact is molded.

[0036]

In Comparative Example 1, a green compact is molded from a molding powder, which has zinc stearate added as lubricant to said iron based powder, in a state in which the molding temperature is kept at room temperature, that is, in a state in which the temperature of both the molding powder and the molding die is kept at room temperature. In Comparative Example 1, with the amount of the molding powder taken as 100%, 0.5% of zinc stearate is added. In Comparative Example 2, a green compact is molded from a molding powder, which has lubricant (lubricant described in US Patent No. 4,955,798) used for warm molding added to said iron based powder, in a state in which the molding temperature is set at 150°C, that is, in a state in which the temperature of both the molding powder and the molding die is set at 150°C. In Comparative Example 1, with the amount of the molding powder taken as 100%, 0.5% of lubricant used for warm molding is added.

[0037]

Table 1

	Lubrication	Molding temperature
Comparative Example 1	Zinc stearate	Room temperature
Comparative Example 2	Lubricant for warm molding	160°C
Application Example 1	Die lubrication	150°C
Application Example 2	Room temperature	180°C

Test results of density measurement of the green compacts are illustrated in Figure 4. As can be seen from Figure 4, even with the same molding surface pressure, density of the green compacts in Comparative Examples 1 and 2 is lower, while density of the green compacts formed in Application Examples 1 and 2 is higher. Especially in Application Example 2, with molding temperature set at 180°C, density of the green compact is the highest. It can be seen that even if the molding surface pressure is kept the same (= 7 ton/cm^2) as the green compact is formed, by using the method in this application example, density of the green compact can be increased. The reason is believed to be a good fineness of the pores as no lubricant is used.

[0038]

② Furthermore, when density of green compacts is set at 7.1 g/cm^3, flexural strength of the green compacts in the application examples and comparative examples was measured. Measurement of flexural strength is based on the standard of Japanese Powder Metallurgical Industry Association (JPMA M 09-1992). Test results are illustrated in Figure 5. As can be seen from Figure 5, strength of the green compacts in Comparative Examples 1 and 2 is lower, while the green compact formed in Application Example 1 has a high strength over 3 kg/cm^2. It can be seen that even if density of the green compacts is kept the same, by using the method in this application example, strength of the green compact can be increased. The reason is believed to be that solidification (entanglement of powder) among the powder particles becomes stronger as no lubricant is used.

[0039]

(Test Example 2)

① In this test, as green compacts were formed by compression-molding the molding powder, which is formed from a mixture of iron based powder and graphite powder, by changing the molding surface pressure from 5 ton/cm^2 to 6 ton/cm^2 to 7 ton/cm^2, changes in density of the green compacts were studied in both the application examples and comparative examples. Measurement of density is the same as aforementioned, and it is based on the standard of Japanese Powder Metallurgical Industry Association (JAMA M 09-1992). Also, in both said application examples and comparative examples, the proportion of the graphite powder in the molding powder is 5 wt%.

[0040]

In Application Example A, said Distaloy AE (Hoganas Co) was adopted as the iron based powder, and target temperature of both the powder and the molding die was set at 150°C. Target composition of Distaloy AE is the same as aforementioned, that is, the composition by weight is

of Fe, 4% Ni, 1.5% Cu and 0.5% Mo. Test results in Application Example A are shown in Figure 6. The abscissa in Figure 6 represents the molding surface pressure, and the ordinate represents density of the green compacts. RT stands for room temperature in Figure 6.

[0041]

In Comparative Example B, Distaloy AE (Hoganas Co) was used as the iron based powder, and temperature of both the powder and the molding die was set at room temperature. In Comparative Example C, Distaloy AE (Hoganas Co) with zinc stearate added in was used as the iron based powder, and temperature of both the molding powder and the molding die was set /6
at room temperature. In Comparative Example D, Ancordense (Hoganas Co), which is prepared by adding a lubricant for high-temperature use that does not melt even in the high-temperature range instead of zinc stearate, was used as the iron based powder. In this comparative example, temperature of both the powder and the molding die was set at room temperature.

[0042]

In Comparative Example E, Ancordense was used as the iron based powder, and the temperature of both the powder and the molding die was set at room temperature. As can be seen from Figure 6, in Comparative Examples C, D and B, in which the green compacts are molded from the powder and the molding die at temperature in the room-temperature range, density of the green compacts is low. Also, in Comparative Example E, in which a lubricant for high-temperature use is added to the molding powder, density of the green compact is high as molding surface pressure is in the range of 5-6 ton/cm^2, while as molding surface pressure approaches 7 ton/cm^2, the effect of increase in density levels off.

[0043]

On the other hand, in Application Example A, in which target temperature of both the powder and the molding die is set at 150°C, even when the molding surface pressure is set at 7 ton/cm^2, the effect of increase in density does not level off. That is, as seen in Figure 6, density in Application Example A is higher than that in Comparative Example E if molding surface pressure is at 7 ton/cm^2. The reason is believed to be as follows: in the case that molding surface pressure is high and lubricant is contained, the portion corresponding to the lubricant is not substantially filled with metal powder; instead, it substantially becomes pores, so that a high-density green compact is not formed. On the other hand, when there is no lubricant, there is no such problem.

② Also, for the green compacts obtained in said Application Examples A-E, testing was carried out to study their flexural strength. Measurement of the flexural strength is carried out on

the base of the standard of Japanese Powder Metallurgical Industry Association (JPMA M 09-1992). The results of the test are shown in Figure 7. In Figure 7, the abscissa represents the density of the green compact, and the ordinate represents the strength of the green compact. In Application Example A, when the density of the green compact is as high as in the range of 7.1-7.3 g/cm^3, the strength of the green compact is increased to about 3-4.7 kgf/mm^2. That is, in Application Example A, the slope of increase of the characteristics curve is large.

[0044]

On the other hand, in Comparative Example E, even when the density of the green compact is increased to 7.1-7.3 g/cm^3, the strength of the green compact is still merely a little over 2.5 kgf/mm^2 with little increase. That is, in Comparative Example E, the slope of rise of the characteristic curve is small.

③ In use, said green compact is sintered to form a sintered body. In order to further increase the density, it is preferred that forging be performed after sintering to form a sintered forged body under high pressure. In the practical operation in this case, it is necessary to transport the sintered body from the sintering step to the forging step. Consequently, the sintered body makes contact with the ambient atmosphere during the process of said transportation. If the sintered body has a high degree of exposure to the ambient atmosphere, when it is forged, surface defects are developed on the surface of the sintered forged body, and this is undesired with respect to maintaining the strength of the sintered forged body.

[0045]

In the test, after a sintered body is formed by sintering said green compact in the sintering temperature range (1120-1150°C), the sintered body is exposed to the ambient atmosphere for a prescribed time T (T=10 sec). Then, the sintered body is hot forged to form a sintered forged body. Then, the proportion of area of the surface defects of the sintered forged body is measured. The results are shown in Figure 8, with density ρ of the green compact taken as a parameter.

[0046]

In Figure 8, the abscissa represents the distance from the surface of the sintered forged body, and the ordinate represents the proportion of area of the surface defects. It can be seen from Figure 8 that the proportion of area of the surface defects depends significantly on the density of the green compact. That is, when the green compact has a low density (ρ=5.8), the proportion of area of the surface defects of the sintered forged body is high. It is believed that in this case, fineness of the surface decreases, and the sintered body is prone to surface oxidation. On the other hand, if the green compact has a high density (ρ=6.8), the proportion of area of the

surface defects becomes smaller. It is believed that in this case, fineness of the surface becomes better, and it becomes harder for surface oxidation of the sintered body to make progress.

[0047]

Consequently, the method of this invention can effectively increase the density of the green compact, and it is preferred in reducing the surface defects of the sintered forged body. As a result, it is favorable for increase in the strength of the sintered forged body. Figure 9 is a diagram illustrating the relationship between the density of the green compact and the proportion of area of the surface defects on the sintered forged body. It can be seen from the characteristic curve in Figure 9 that when the density of the green compact becomes lower, the proportion of area of the surface defects of the sintered forged body becomes larger. On the other hand, when the density of the green compact becomes higher, the proportion of area of the surface defects of the sintered forged body becomes smaller.

[0048]

(P.S.) From the aforementioned application examples, the following technical ideas have been obtained.

① According to Claim 1, the powder molding method is characterized by the fact that the molding powder and the molding die are substantially at the same temperature.

② According to Claim 1, the powder molding method is characterized by the fact that the temperature of the molding powder is lower than the temperature of the molding die.

③ According to Claim 1, the powder molding method is characterized by the fact that the temperature of the molding powder is higher than the temperature of the molding die.

④ A Powder molding method characterized by the fact that a powder box that can be driven to move between a standby position away from the molding die to a position facing the molding die is used, and the interior of the standby powder box can be maintained in reduced pressure state or vacuum state.

⑤ A method for manufacturing a sintered forged body characterized by the fact that the following steps of operation are performed in order: a step in which a molding die for powder molding equipped with die surfaces that define the molding cavity and a molding powder substantially free of lubricant are used, and in which a heating operation is performed to heat said molding die and said molding powder to within a temperature range of 150-400°C, and, at the same time, a coating operation is performed to coat said lubricant on the die surfaces of said molding die; a step in which said molding powder is filled in the molding cavity of said molding die; a step in which said molding powder filled in said molding cavity is compression-molded to form a green compact; a step in which the green compact is sintered to form a sintered body; and

a step in which the sintered body is forged to form the desired sintered forged body. This method can realize a high density of the green compact. Consequently, it can reduce surface defects so as to guarantee the strength of the sintered forged body.

[0049]

Effect of the invention

According to the method of this invention, the following steps of operation are performed /7 in order: a step in which a molding die for powder molding equipped with die surfaces that define the molding cavity and a molding powder substantially free of lubricant are used, and in which a heating operation is performed to heat said molding die and said molding powder to within a temperature range of 150-400°C, and, at the same time, a coating operation is performed to coat said lubricant on the die surfaces of said molding die; and a step in which said molding powder is filled in the molding cavity of said molding die. As a result, it is favorable for increasing the density and strength of the green compact.

[0050]

Increase in the density of the green compact is favorable in reducing the pores on the surface of the green compact. Consequently, when the green compact is sintered and forged, surface defects on the surface of the sintered forged body can be reduced effectively, and this is favorable for further increase in the strength of the sintered forged body.

Brief description of the figures

Figure 1 is a diagram illustrating the constitution of an application example.

Figure 2 is a diagram illustrating the constitution of the various steps of operation in the application example.

Figure 3 is a diagram illustrating the constitution of other examples.

Figure 4 is a graph illustrating the density of the green compact when the molding surface pressure is at 7 ton/cm^2.

Figure 5 is a graph illustrating the strength of the green compact when the density of the molding is 7.1 g/cm^3.

Figure 6 is a graph illustrating the relationship between the molding surface pressure and the density of the green compact.

Figure 7 is a graph illustrating the relationship between the density of the green compact and the strength of the green compact.

Figure 8 is a graph illustrating the relationship between the distance from the surface of the sintered forged body and the proportion of area of surface defects of the sintered forged body.

Figure 9 is a graph illustrating the relationship between the density of the green compact and the proportion of area of the surface defects of the sintered forged body.

Explanation of symbols

1 Molding die

11 Die mold

13 Upper punch die

17 Molding cavity

11c, ~~12c~~ 2c, 13c, 73 Heater

2 Powder box

3 Spray nozzle

/8

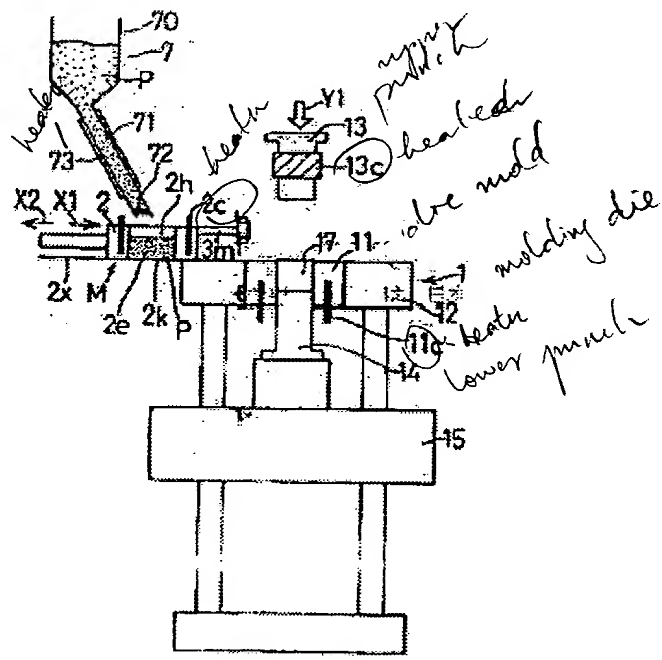

Figure 1

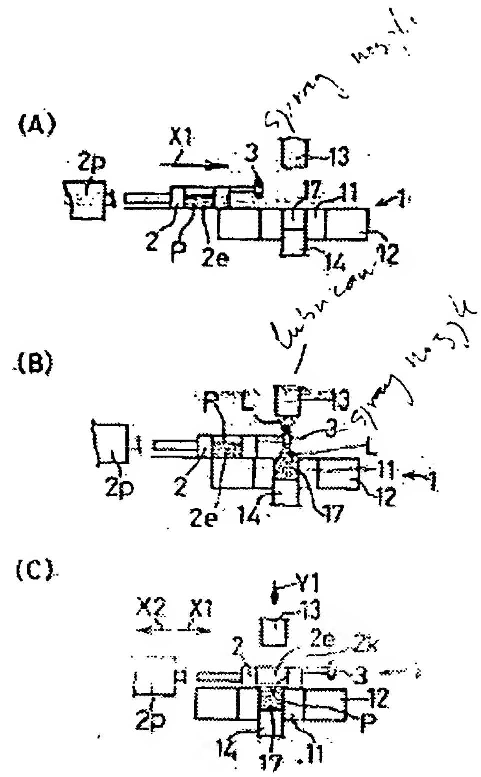

Figure 2

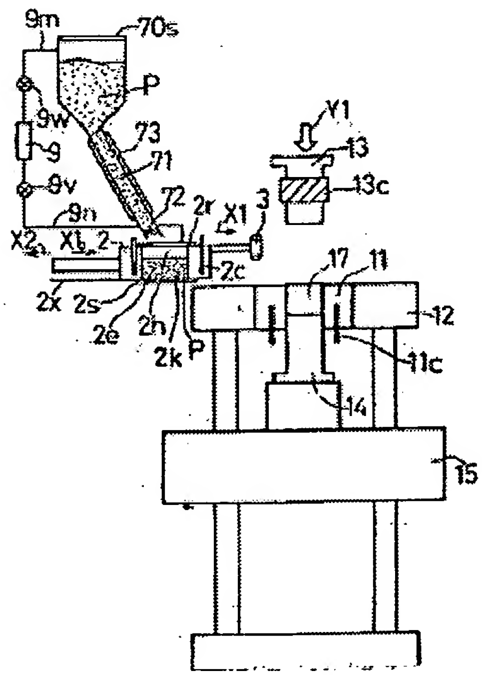

Figure 3

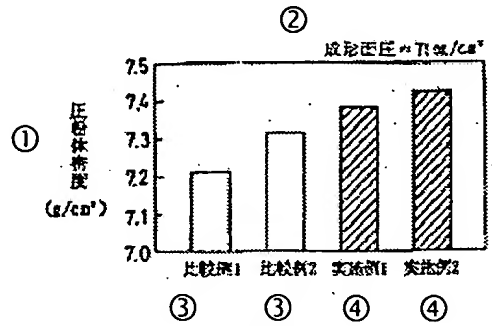

Figure 4

Key: 1 Density of green compact
2 Molding surface pressure
3 Comparative Example
4 Application Example

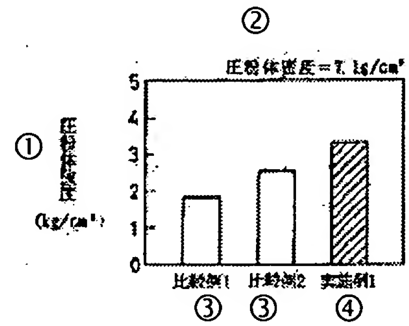

Figure 5

Key: 1 Strength of green compact
2 Density of green compact
3 Comparative Example
4 Application Example

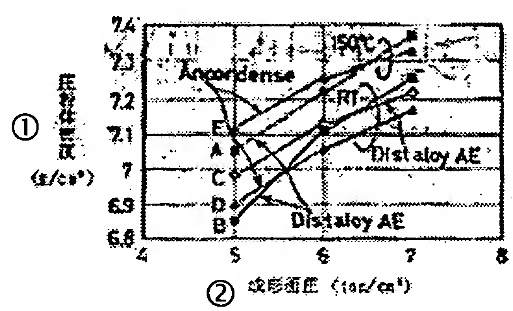

Figure 6

Key: 1 Density of green compact
2 Molding surface pressure